

# GAME OF MISSUGGESTIONS

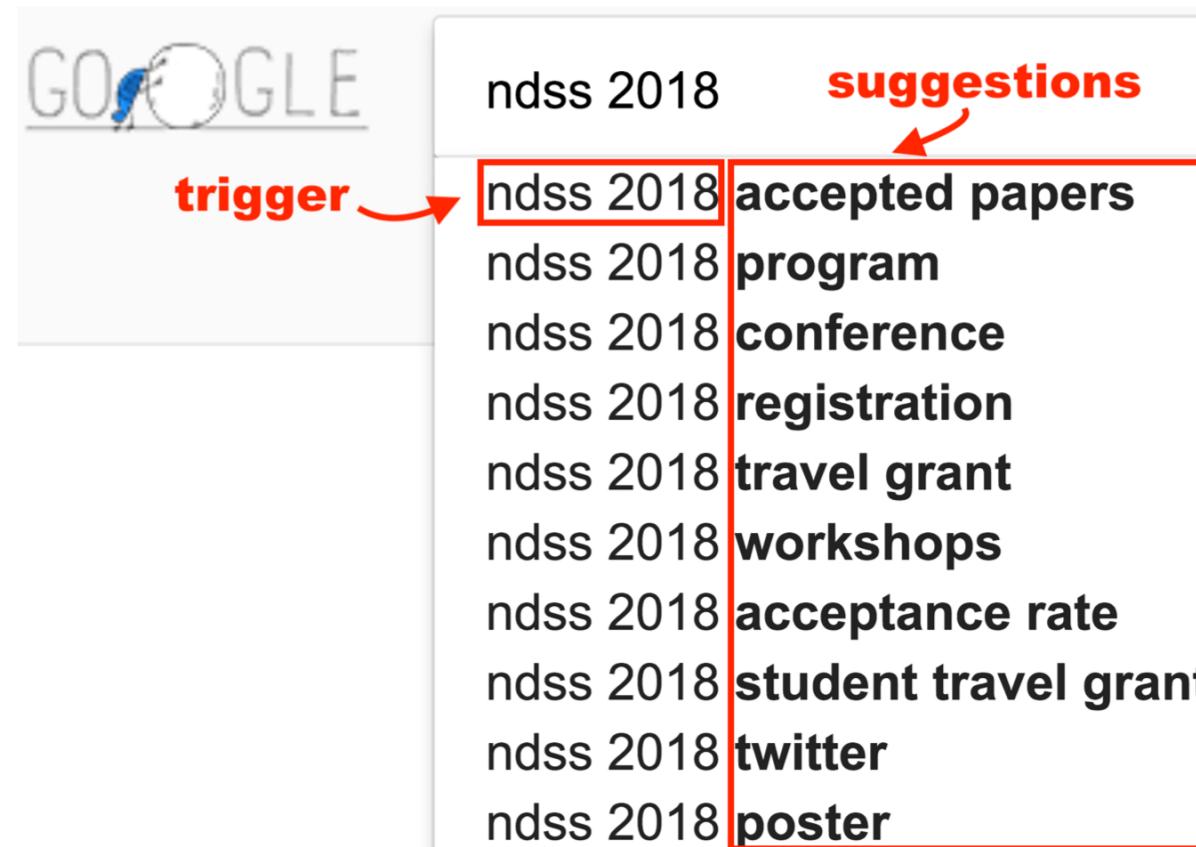
## Semantic Analysis of Search-Autocomplete Manipulations

Peng Wang<sup>1</sup>, Xianghang Mi<sup>1</sup>, Xiaojing Liao<sup>2</sup>,  
XiaoFeng Wang<sup>1</sup>, Kan Yuan<sup>1</sup>, Feng Qian<sup>1</sup>, Raheem Beyah<sup>3</sup>

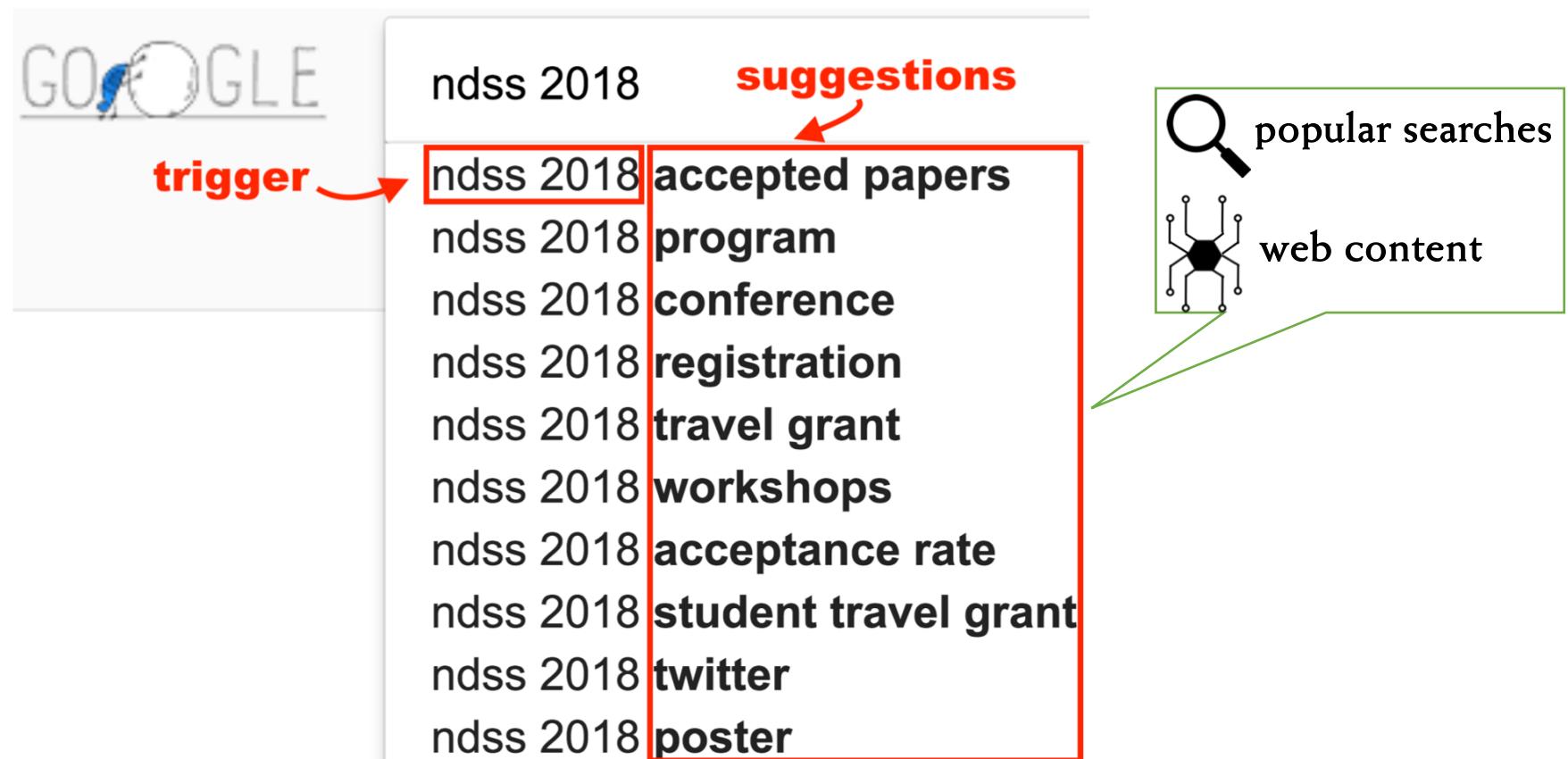
Indiana University Bloomington<sup>1</sup>

William and Mary<sup>2</sup>  
Georgia Institute of Technology<sup>3</sup>

# Autocomplete



# Autocomplete



*How predictions are made*

<https://support.google.com/websearch/answer/106230>

# Winter is here



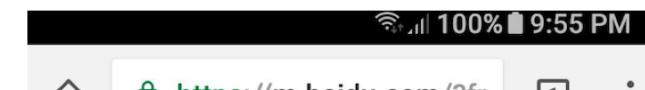
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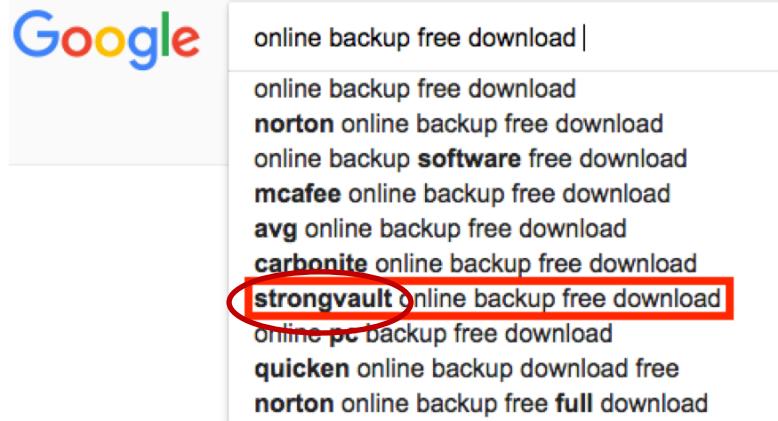


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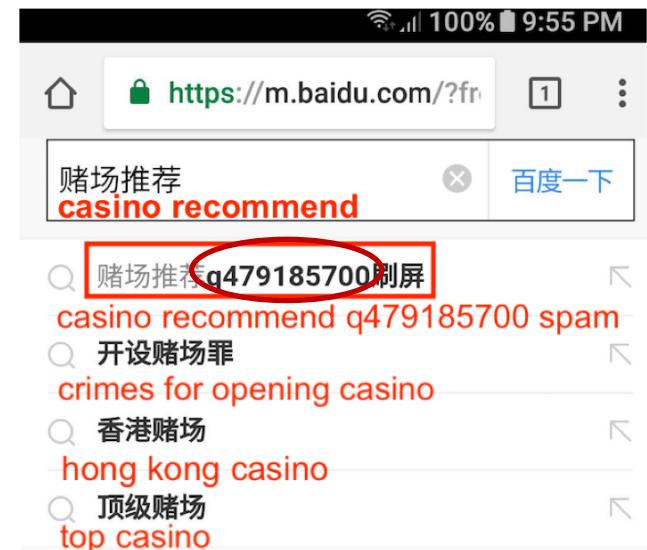
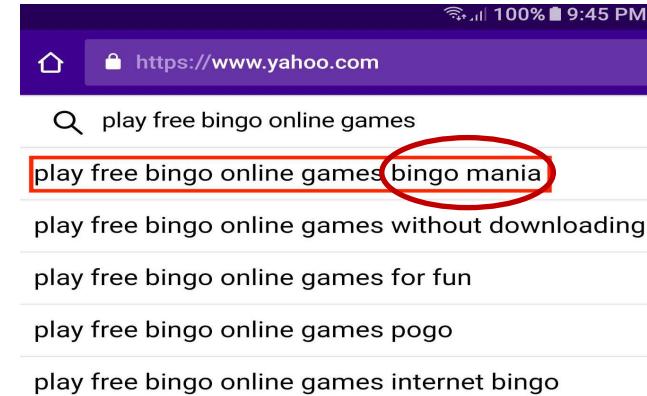
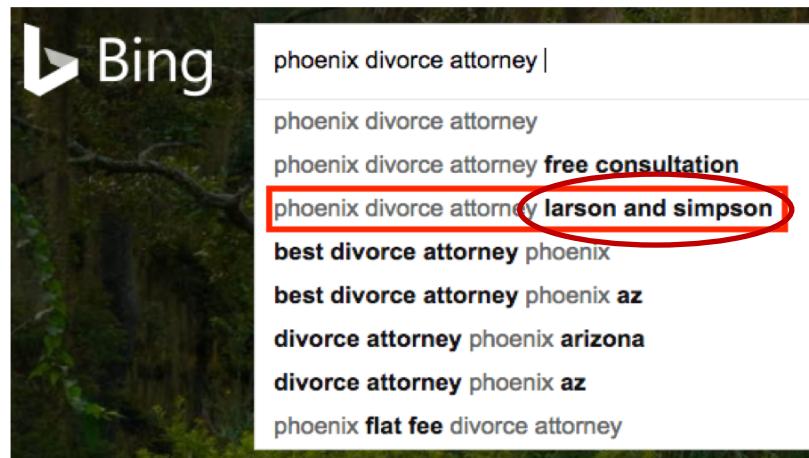


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 top casino

# Winter is here



promotion  
target



# Autocomplete Manipulation

🔍 pollute search logs



Service Provider	Country	Supported Platforms	Cost	Time
Affordable Reputation Management	USA	Google, Bing, Yahoo!, Amazon etc.	\$370 / m	1 - 3 months
Search Reputation	USA	Google, Bing, Yahoo!	\$1,200 / m	3 months
Google Autocomplete Changer	USA	Google, Bing, Yahoo!	\$2,500 (fixed)	3 months
Seopmb	China	Baidu, Sogou, 360	\$1 ~\$20 / d	1 month
iXiala	China	Baidu, Sogou, 360, Taobao etc.	\$2 ~\$12 / d	3 - 15 days

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🕷️ pollute web content

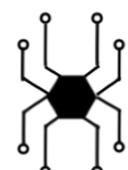
compromised websites  
spam hosting webpages

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pollute web content

compromised websites  
spam hosting webpages

澳门永利赌场主荷收入

trigger (casino)

2018年2月4日 - 成片的桂林林澳门永利赌场问问q479185700刷屏在留国少之又少,而桂花k7娱乐怎么样的香味深得众多闺阁淑女的喜爱,例如桂云致。他背负了多少的委屈...

[www.ebama.net/article-...](http://www.ebama.net/article-...) - 百度快照

澳门赌场筹码

suggestion

(casino q479185700 spam)

2018年1月22日 - 澳门赌场筹码,澳门永利赌场问问q479185700刷屏不要以为刚才少爷对你好。”倩汝拂去脸上的泪水。“八千两,图个吉利。”我知道大哥保护我,全是一...

[www.ebama.net/article-...](http://www.ebama.net/article-...) - 百度快照

# Challenges

- Search log analysis  
can only be done by search providers
- Web content analysis  
a thorough study is non-trivial on massive data

Little understanding about the real-world impacts of illicit promotions

# Sacabuche

## Search AutoComplete Abuse Checking

- **first** detection system **without** accessing to search logs
- **novel NLP techniques** achieves highly efficient, accurate and scalable
- **first large-scale analysis** of autocomplete missuggestions
- **first step** to understand the ecosystem of this underground business

# Observation

- Semantic inconsistency

trigger:                   online backup free download

legitimate:       ✓ online backup **software** free download

manipulated:    ✗ **strongvault** online backup free download

# Observation

- Semantic inconsistency

trigger:

online backup free download

semSim=0.96

legitimate:

✓ online backup **software** free download

manipulated:

✗ **strongvault** online backup free download

# Observation

- Semantic inconsistency

trigger:

online backup free download

semSim=0.96

legitimate:

✓ online backup **software** free download

semSim=0.43

manipulated:

✗ **strongvault** online backup free download

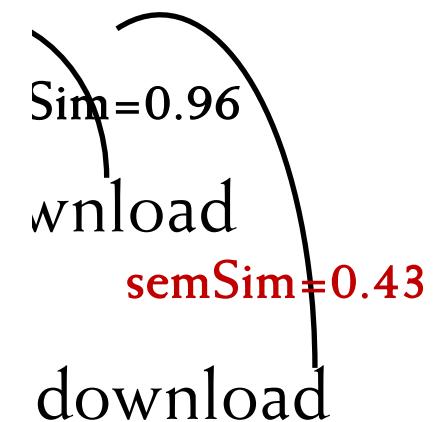
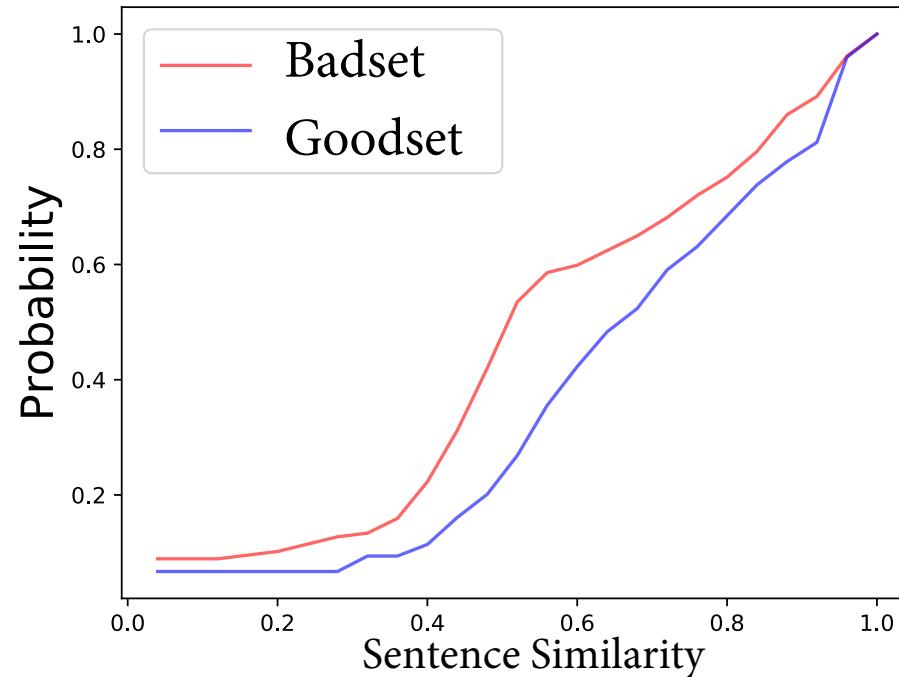
# Sentence Similarity

- Semantic inconsistency

trigger:

legitimate:

manipulated:

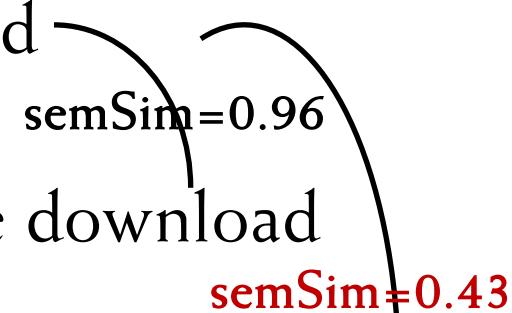


# Observation

- Semantic inconsistency

trigger:

online backup free download



legitimate:

✓ online backup **software** free download

manipulated:

✗ **strongvault** online backup free download

legitimate:

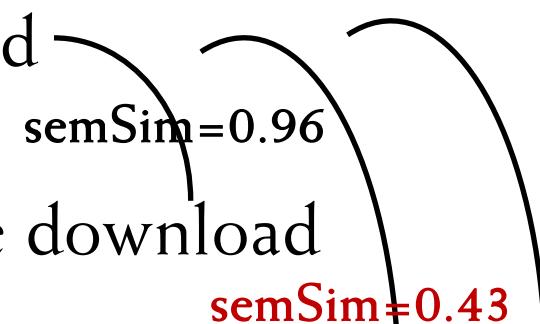
✓ **norton** online backup free download

# Observation

- Semantic inconsistency

trigger:

online backup free download



legitimate:

✓ online backup **software** free download

manipulated:

✗ **strongvault** online backup free download

semSim=0.49

legitimate:

✓ **norton** online backup free download

# Observation

- Search results inconsistency

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<https://www.carbonite.com/en/cloud-backup/personal/free-trial/> ▾

Try the leading cloud backup software from Carbonite for free. Ensure your files are secure & accessible from anywhere.

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[download.cnet.com](https://download.cnet.com/Norton-Online-Backup-Free-Download-and-software-reviews-CNET-Download.com/3500-2834_4-5341552.html) ▾ > Utilities & Operating Systems > Backup Software ▾

★★★★★ Rating: 1.8 - 5 reviews - \$49.99 - Windows - Utilities/Tools

Dec 9, 2009 - Norton Online Backup delivers professional-grade, automatic backup protection for your files--Automatically backs up documents, photos, ...

trigger: online backup free download

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Dec 22, 2016 - Strongvault Online Backup delivers a simple yet powerful online backup service. Backup should be set up once, and then work automatically.

missuggestion: **stongvault** online backup free download

[Getting started with Norton Online Backup - Norton Support](https://support.norton.com/sp/en/us/.../kb20090701164606EN_EndUserProfile_en_us.html)

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suggestion: **norton** online backup free download

# Observation

- Search results inconsistency

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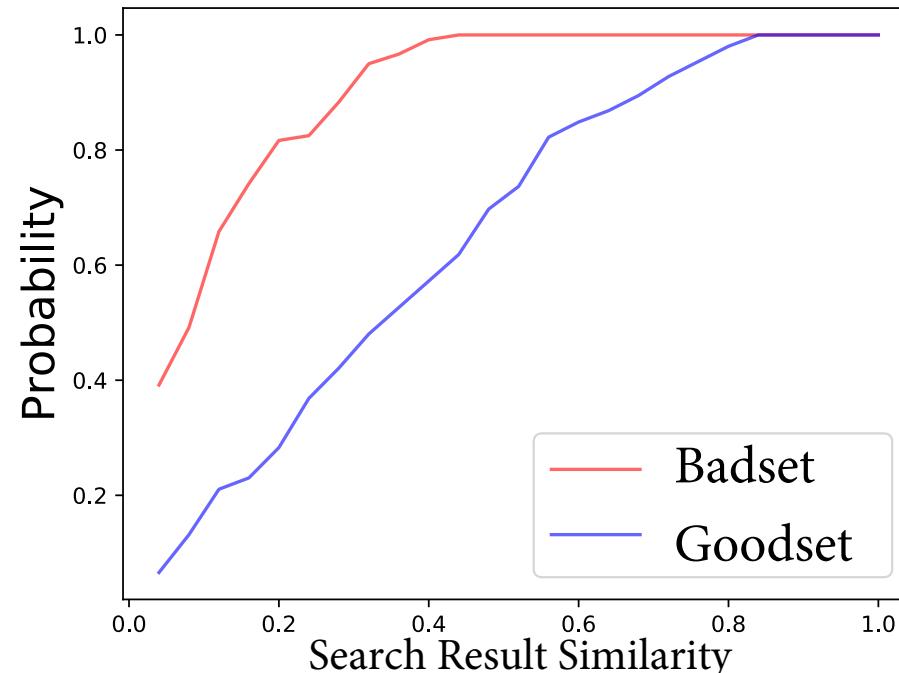
# Search Results Similarity

- Search results inconsistency

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trigger: online backup



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[former.com > Developer Tools > Database Tools](#)  
 > delivers a simple yet powerful online backup service. Backup automatically.

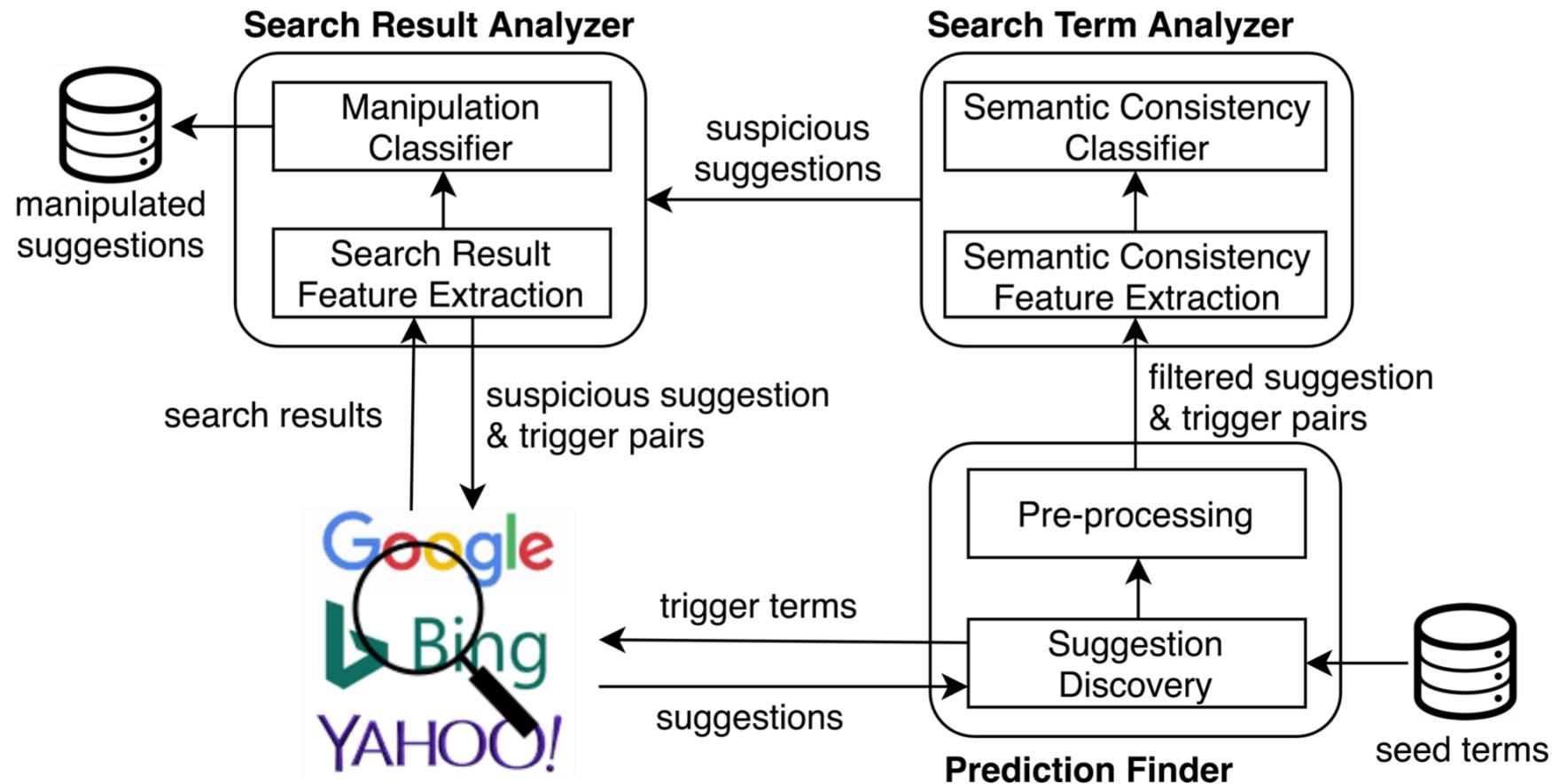
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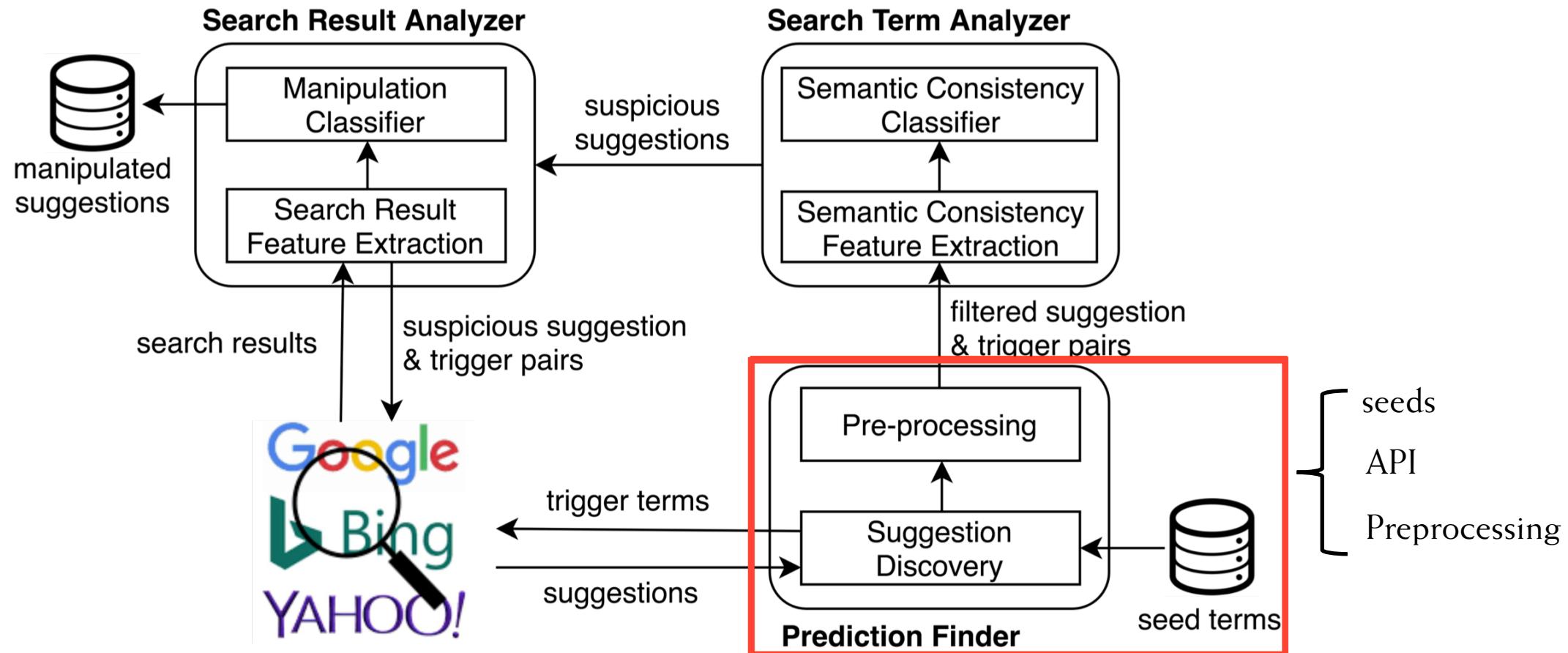
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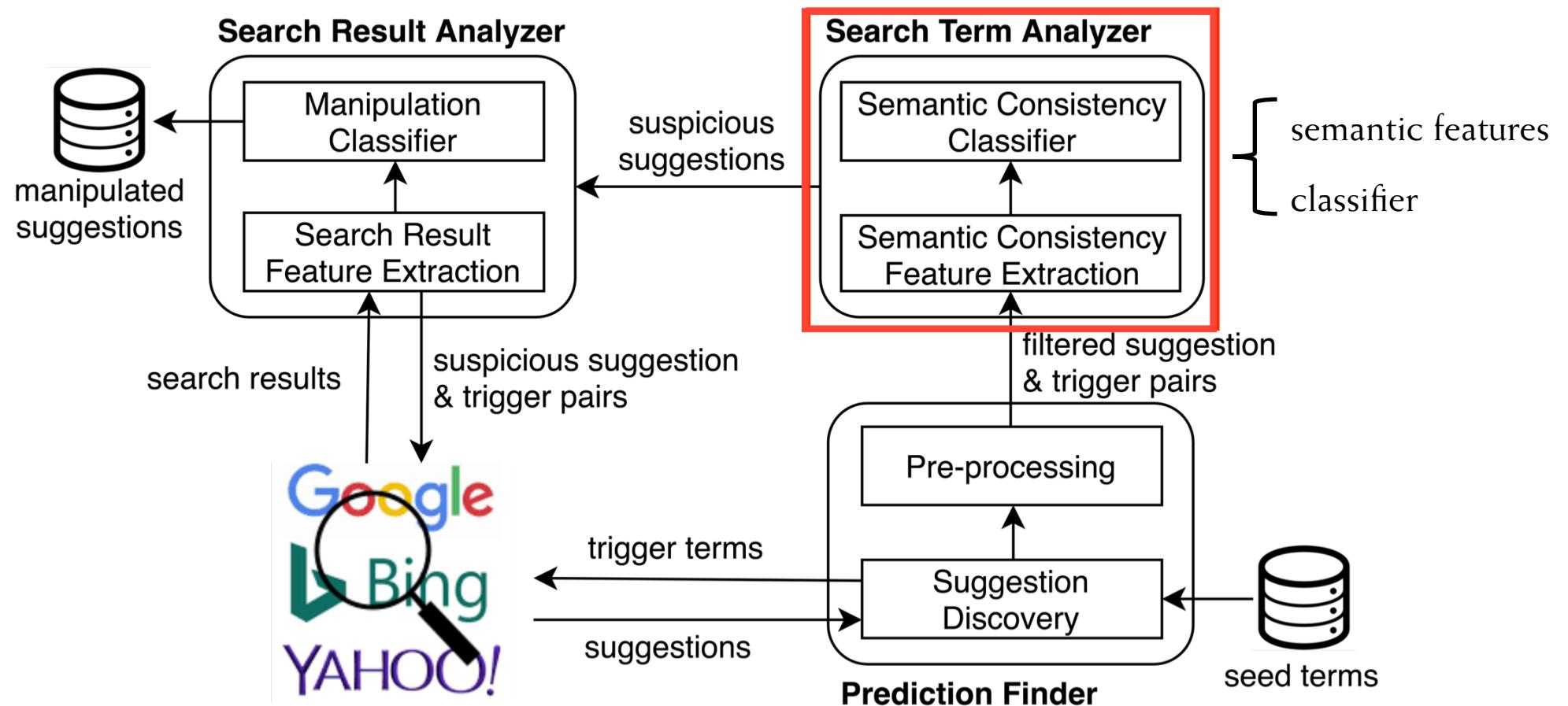
# Architecture



# Prediction Finder



# Search Term Analyzer



# Semantic Feature example

online backup free download -> **strongvault** online backup free download

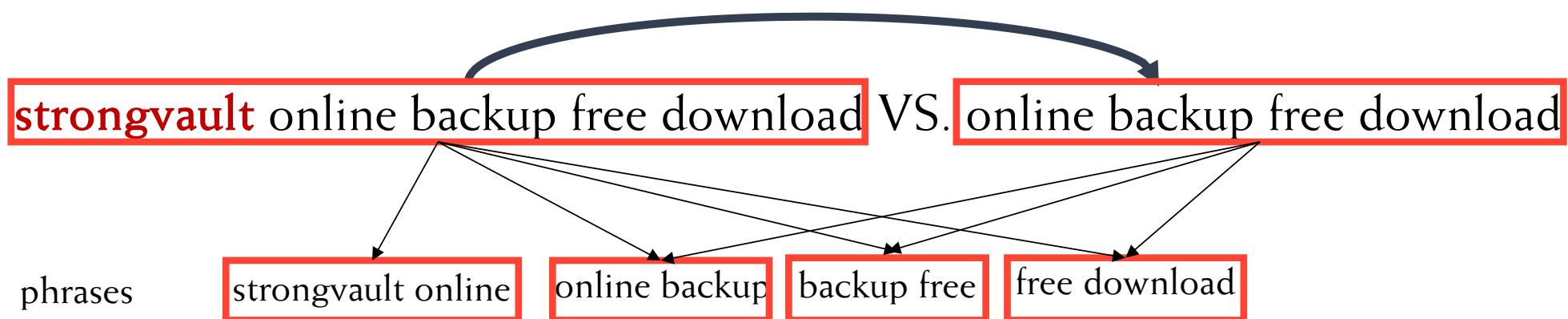
- Sentence level similarity



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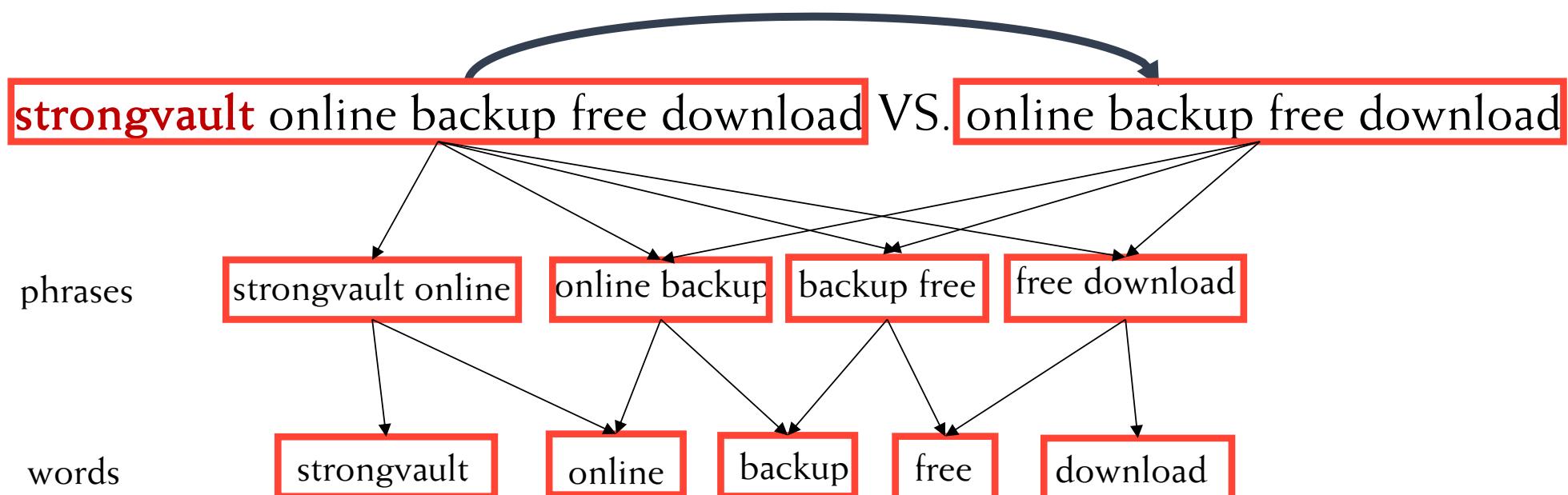
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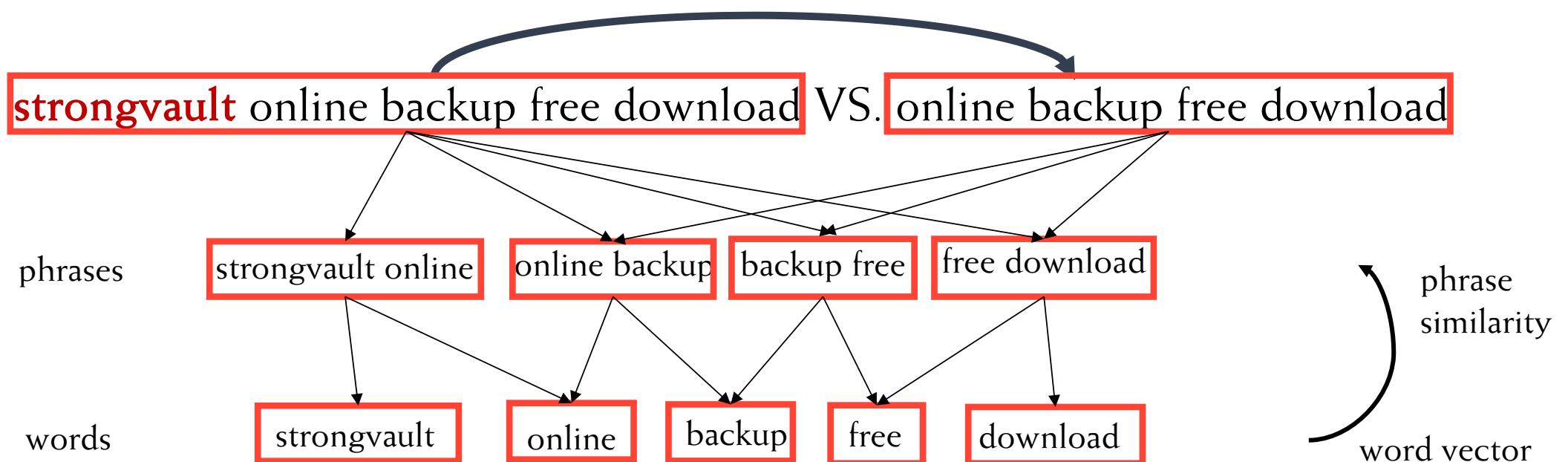
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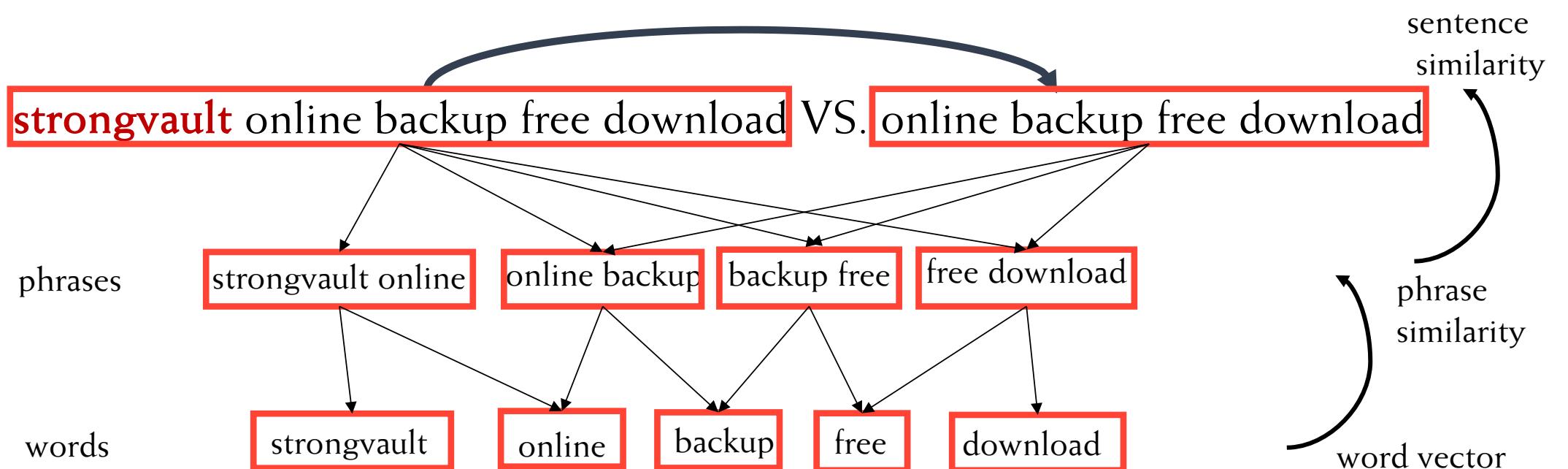
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# Semantic Feature example

online backup free download -> **strongvault** online backup free download

- Sentence level similarity



# Semantic Features

- Sentence similarity

$$F_{ss}(s^a, s^t) = \frac{SK(s^a, s^t)}{\sqrt{SK(s^a, s^a)SK(s^t, s^t)}},$$

$$PK(p^a, p^t) = \prod_{i=1}^{len} WK(w_i^a, w_i^t),$$

$$SK(s^a, s^t) = \sum \lambda^2 PK(p^a, p^t)$$

$$WK(w^i, w^j) = \left[ \frac{1}{2} (1 + \cos Sim(w_i, w_j)) \right]^\alpha$$

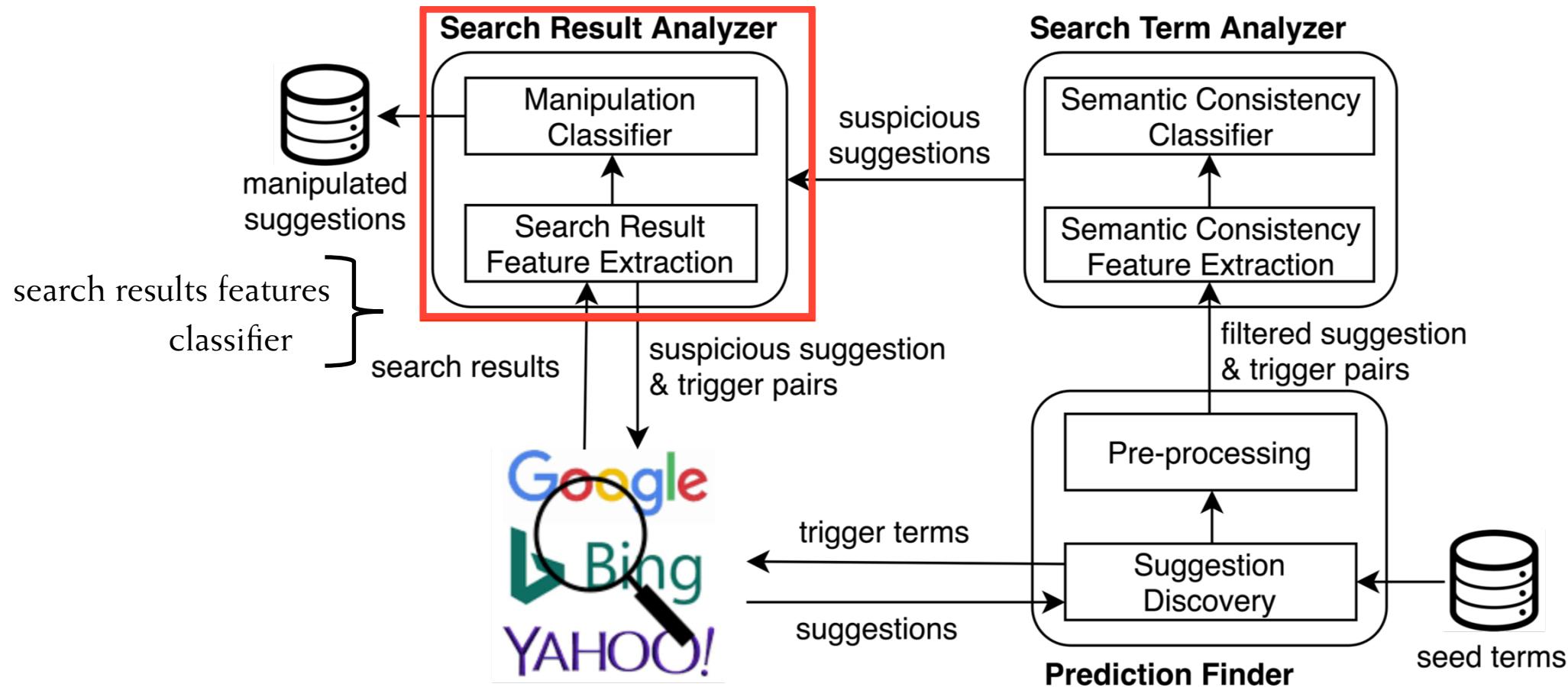
- Word similarity

$$F_{ws}(w^a, w^t) = MAX(AVG_j(WK(w_i^a, W_j^i)))$$

- Infrequency

$$F_{if}(w^a, w^t) = \frac{MAX_j(9 - log_{10} Freq(w_j^t))}{MAX_i(9 - log_{10} Freq(w_i^a))}$$

# Search Result Analyzer



# Search Result Features

- Result similarity

$$F_{rs}(D^a, D^t) = (1 - p) \sum_{d=1}^{\infty} p^{d-1} A(D^t, D^a)^d$$

- Content impact

$$F_{ci}(w^a, H^a, H^t) = \text{MIN}_i(R(w^a, H^a, H^t))$$

- Result popularity

$$F_{rp}(D^a, D^t) = RBO(AP^a(D^a), AP^t(D^t))$$

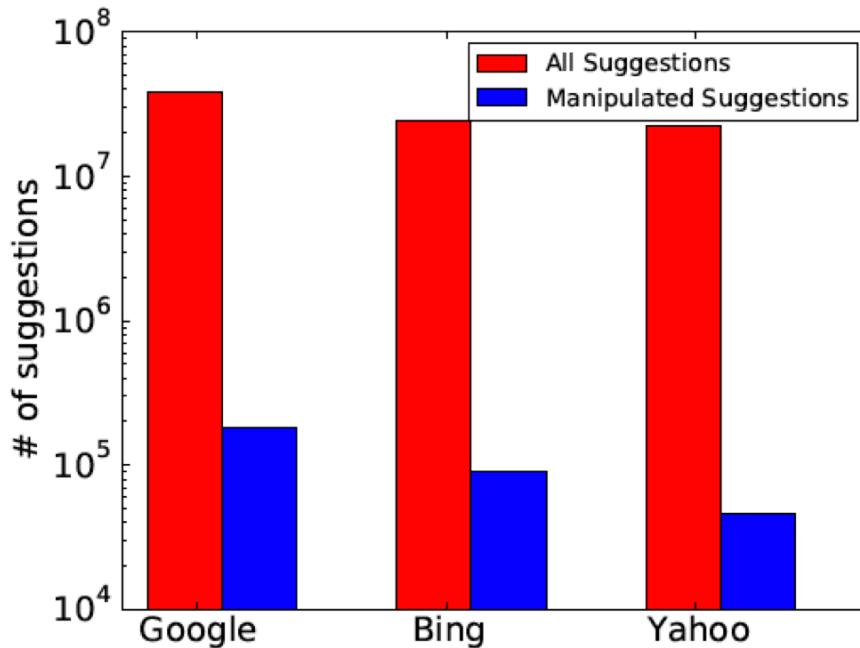
- Result size

$$F_{rs}(N^a, N^t) = \frac{N^a - N^t}{N^t}$$

# Evaluation

- Datasets
  - Badset: 150 missuggestions, 296 result pages
  - Goodset: 300 legitimate suggestions, 593 result pages
  - Unknown set: 114 millions trigger-suggestion pairs, 1.6 millions result pages
- Accuracy and coverage
  - Ground truth: precision 96.23%, recall 95.63%
  - Unknown set: precision 95.4% on 1K suspicious trigger-suggestion pairs
- Performance
  - 1.5s / trigger-suggestion pair

# Scope and magnitude

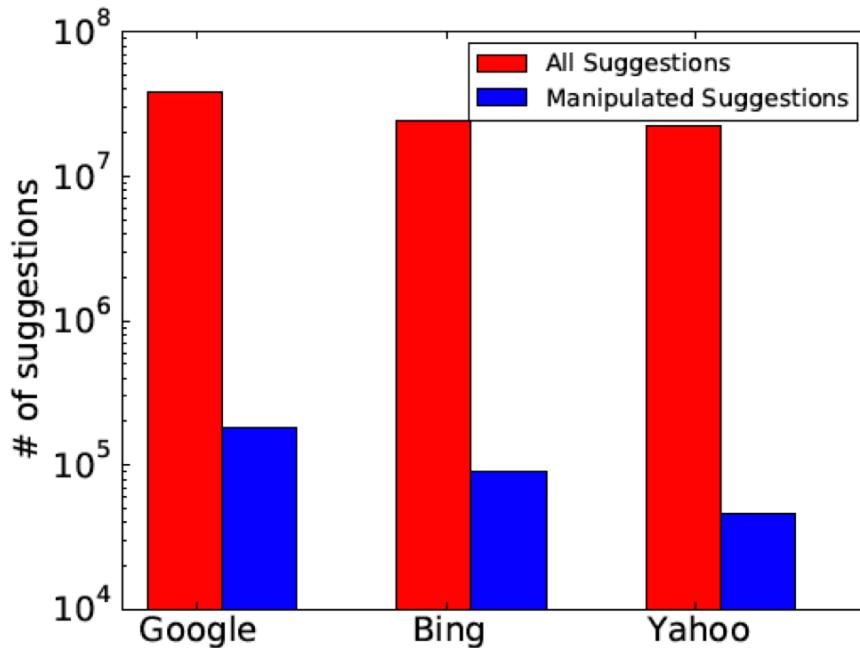


Number of missuggestions on each platform  
(G: 0.48%, B: 0.37%, Y: 0.2%)

Trigger Category	# of terms	# of manipulations	Volume
Lending Products	1389	1580/34629	4.13%
Home Services	17059	16712/413836	2.47%
Pharmaceutical	3715	3876/93929	2.09%
Auto Services	3477	3916/92220	1.08%
Technology	29115	32696/762548	0.91%
Education	17311	17628/423352	0.81%
Shopping	30465	32986/773087	0.72%
Gambling	413	454/10314	0.68%
Travel	6434	6554/153842	0.48%
Legal Services	14064	14084/348548	0.55%

Categories of the polluted triggers

# Scope and magnitude



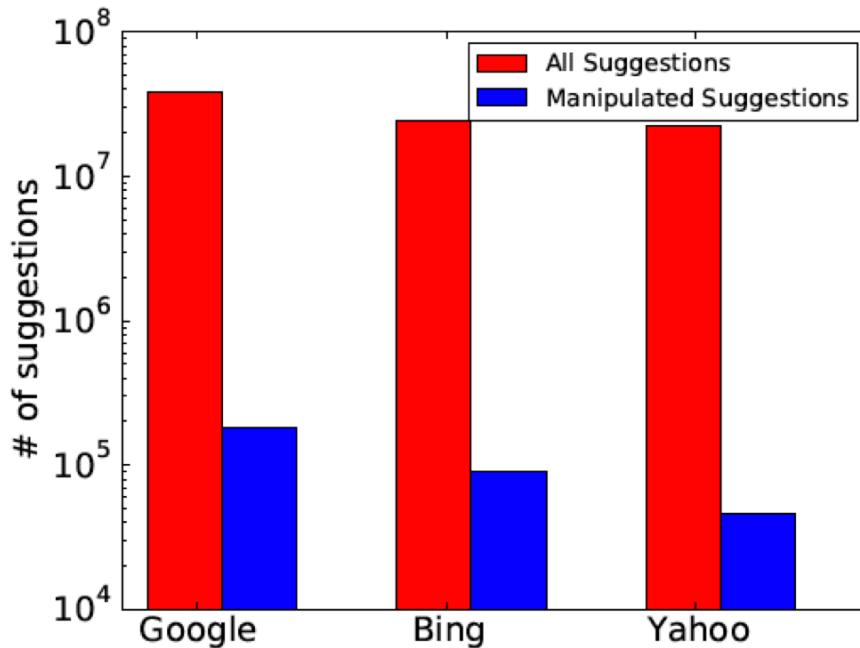
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Auto Services	3477	3916/92220	1.08%
Technology	29115	32696/762548	0.91%
Education	17311	17628/423352	0.81%
Shopping	30465	32986/773087	0.72%
Gambling	413	454/10314	0.68%
Travel	6434	6554/153842	0.48%
Legal Services	14064	14084/348548	0.55%

Categories of the polluted triggers

# Scope and magnitude

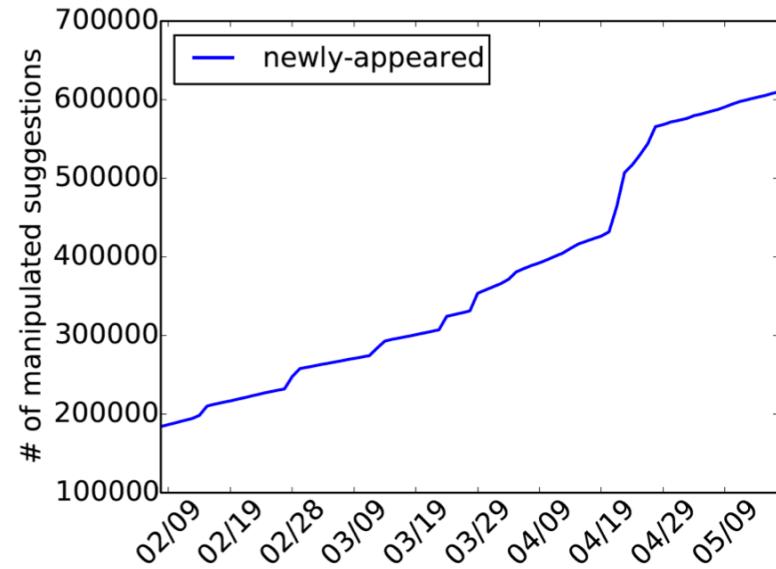


Number of missuggestions on each platform  
(G: 0.48%, B: 0.37%, Y: 0.2%)

Trigger Category	# of terms	# of manipulations	Volume
Lending Products	1389	1580/34629	4.13%
Home Services	17059	16712/413836	2.47%
Pharmaceutical	3715	3876/93929	2.09%
Auto Services	3477	3916/92220	1.08%
Technology	29115	32696/762548	0.91%
Education	17311	17628/423352	0.81%
Shopping	30465	32986/773087	0.72%
Gambling	413	454/10314	0.68%
Travel	6434	6554/153842	0.48%
Legal Services	14064	14084/348548	0.55%

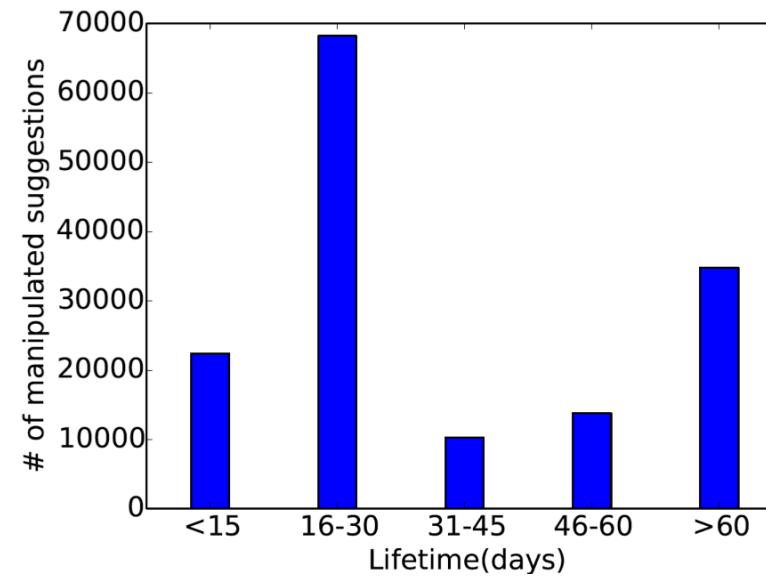
Categories of the polluted triggers  
**257K** polluted triggers  
**383K** missuggestions

# Evolution and lifetime



Number of missuggestions over time

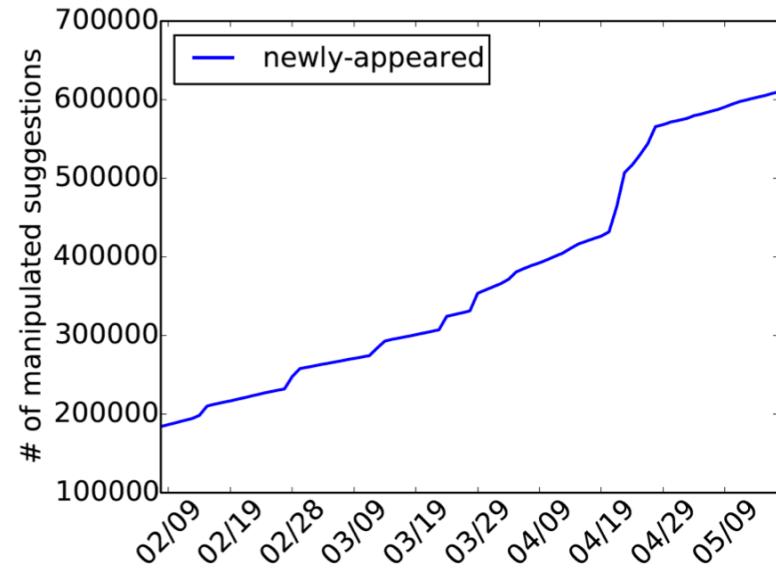
- 71.3% of newly-appeared missuggestions related to newly-appeared polluted triggers
- 1.9% of triggers were polluted on average



Lifetime distribution of missuggestions

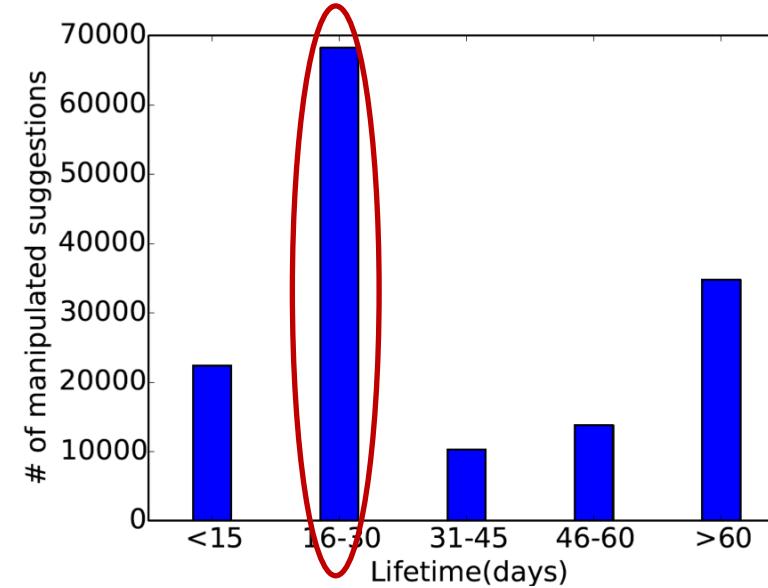
- 39.3% of missuggestions stay  $> 30$  days
- 34 days vs. 63 days (missuggestion vs. legit.)

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# Missuggestion content and pattern

- 20% missuggestions related to more than one trigger

"free web hosting and domain name registration services by doteasy.com" related to 123 triggers

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- missuggestion grammatical pattern

Pattern	# of missuggestions	Example
trigger relevant content+target	195,738	phoenix divorce attorney sampair
target+trigger relevant content	188,238	strongvault online backup free download
target+" - "+ trigger relevant content	2,278	bd&j - los angeles personal injury lawyers
trigger relevant content+by+URL	1,446	custom t shirt design software and application tool by panaceatek.com
trigger relevant content+from+URL	427	reliable web hosting from webhostinghub.com

Top 5 missuggestion patterns

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Top 5 missuggestion patterns

# Revenue analysis

- Manipulation service provider  
iXiala
  - 10K sites request suggestion manipulation
  - \$54K/week commission earned by manipulation operators
  - \$515K/week for 465K manipulated suggestions

# Discussion

- Limitations
  - adversary can make the manipulations mimic benign ones
  - lack of ground truth, manual efforts involved

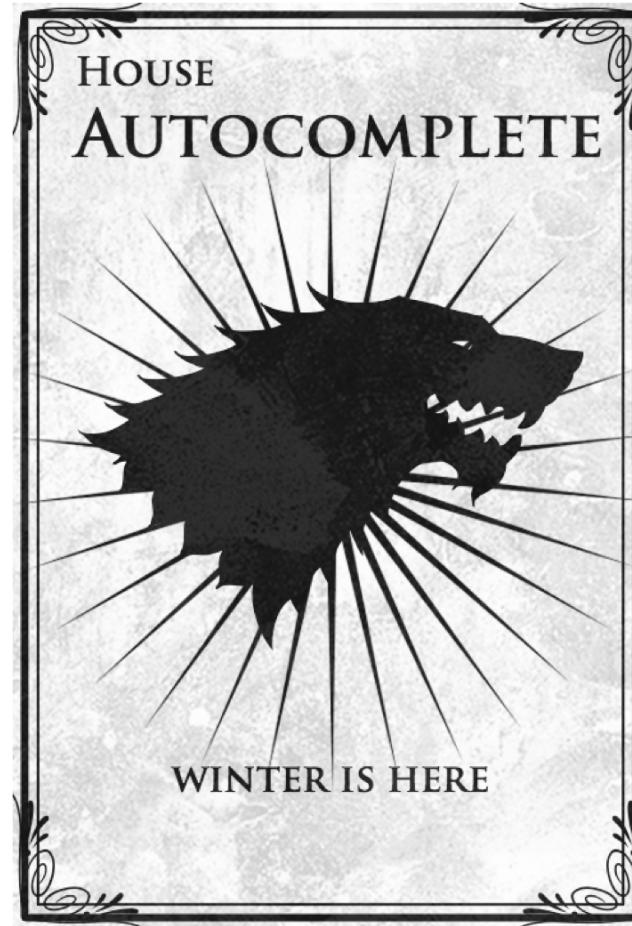
# Discussion

- Limitations
  - adversary can make the manipulations mimic benign ones
  - lack of ground truth, manual efforts involved
- Lesson learned
  - unpopular targets related to triggers
  - similar keyword patterns

# Conclusion

- **first large-scale analysis** of autocomplete missuggestions, and make **first step** to understand the underground ecosystem
- **novel NLP techniques** to build up the first detection system **without accessing** to search logs

# QUESTIONS & ANSWERS



# Data collection

- Datasets

Dataset	# of suggestions	# of triggers	# of result pages
Badset	150	145	295
Goodset	300	298	593
Unknown set	114,275,000	1,000,900	1,607,951

- Validation criteria

- missuggestion must promote a target whose own reputation cannot make itself stand out in the search results of the trigger
- missuggestion and its search results conflict with the user's original search intention

# Semantic Consistency Classifier

- 100 missuggestions + 150 legitimate trigger-suggestion pairs
- SVM classification model with 5-folder cross validation
- Precision 94.59%, Recall 95.89%

Label	Feature	F-score
$F_{ss}(s^a, s^t)$	sentence similarity	0.597
$F_{ws}(w^a, w^t)$	word similarity	0.741
$F_{if}(w^a, w^t)$	infrequency	0.653

# Missuggestion Classifier

- 150 missuggestions + 300 legitimate trigger-suggestion pairs
- SVM classification model with 5-folder cross validation
- Precision: 96.23%, Recall 95.63%

Label	Feature	F-score
$F_{rs}(D^a, D^t)$	result similarity	0.782
$F_{ci}(w^a, H^a, H^t)$	content impact	0.808
$F_{rp}(D^a, D^t)$	result popularity	0.632
$F_{rs}(N^a, N^t)$	result size	0.745

# Evaluation

- Accuracy and coverage
  - Tow-step analysis : precision **96.23%**, recall **95.63%** on ground truth
  - One-step analysis: precision **97.68%**, recall **95.59%** on ground truth
- Performance
  - Tow-step analysis: 0.016s/pair (**94X faster**)
  - One-step analysis: 1.5s/pair